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Research

Normative Data for Optic Disc Vertical Cup-to-Disc Ratio and Intraocular Pressure in London 2012 Competitors and Support Teams

Penny J D'Ath[1*], Stefano Ceccon[1], W David Thomson[1] and Clare M Wilson[2]

[1]*Division of Optometry and Visual Science, City, University of London, Northampton Square, London, EC1V 0HB, United Kingdom*

[2]*Chelsea and Westminster Hospital NHS Foundation Trust, 369 Fulham Road, London, SW10 9NH, United Kingdom*

Abstract

Background / Aims

The aims of this study were to identify normative values in vertical cup-to-disc ratio (CDR) and intraocular pressure (IOP) measurements in a unique sample of competitors and non-competitors at London 2012 according to continents and geographical sub-regions and find a suitable tool for mapping results across the world.

Methods

Data from all patients seen in the eye clinic for the London 2012 Olympic and Paralympic Games were used in this study. Patients were categorized into countries using the United Nations Geographical Sub-regions classification.

All patients underwent a full optometric eye examination and clinical details including cup-to-disc ratio were recorded. Intraocular pressures were also recorded via non contact methods using the Topcon TRK-1P. Data was analyzed using R statistical software and SPSS. Continent and sub-continent level choropleth maps were produced using GGPlot2 package.

Results

Our study used a sample of 2,077 patients for analysis. The mean age across all the continents ranged from 43.44 years in the Americas to 47.11 years in Europe with an overall mean age of 45.12 (SD = 13.62 years).

A CDR was recorded in 1,566 right eyes (OD). A Games-Howell post-hoc test revealed that Africa had statistically significantly larger CDRs (0.34 +/- 0.16) than both Europe (0.29 +/- 0.12, p = 0.00) and Asia (0.31, 0.15, p = 0.04) in this unique sample. In addition, within geographical sub-regions, Western Africa had statistically larger CDRs (0.36 +/- 0.18) than Western Asia (0.27 +/- 0.14, p = 0.02), Eastern Europe (0.29 +/- 0.12, p = 0.01) and Northern Europe (0.29 +/- 0.13, p = 0.03).

A total of 1,621 IOP measurements were recorded for the right eye (OD). A Tukey post-hoc test revealed that Oceania had statistically lower IOPs (15.45 +/- 2.57) than Europe (16.93 +/- 2.98, p = 0.01), Asia (16.95 +/- 2.80, p = 0.01), the Americas (16.53 +/- 2.73, p = 0.02) and Africa (16.41 +/- 3.17, p = 0.05).Within geographical sub-regions, Northern Africa had statistically significantly lower IOPs (15.85 +/- 2.92) than Western Africa (17.18 +/- 2.97, p = 0.02), Western Asia (17.58 +/- 2.83, p = 0.04) and Eastern Europe (17.10 +/- 3.06, p = 0.02).

Finally, our study found that competitors had significantly smaller CDRs (U = 66583.50, p = 0.01).and lower IOPs than non-competitors (U = 79544.50, p = 0.01).

Conclusions

This is the first study to map out cup-to-disc ratio and intraocular pressure in a unique sample of competitors and non-competitors at London 2012 by continent and geographical sub-regions. The authors hope that this data may have benefits globally and that data from future Olympic and Paralympic Games can be added to this information to produce larger, more comprehensive data sets in the future.

Introduction

Vertical cup-to-disc ratio (CDR) is commonly used in ophthalmic

***Corresponding author:** Penny J D'Ath, Division of Optometry and Visual Science, City, University of London, Northampton Square, London, EC1V 0HB, United Kingdom, E-mail: penny.dath@gmail.com

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settings primarily as a means of detecting suspect glaucoma. It is derived from the estimation of the vertical length of the cup compared to the vertical length of the disc and is commonly measured in decimals to one or two decimal places [1]. Despite being a subjective measurement with known inter-variability between practitioners as well as intra-variability with the same practitioner [2-5], it still remains a quick, easy, useful and commonly used measurement amongst eye care professionals incase-finding for glaucoma [6].

Disc size has been shown to vary with parameters including age [7], gender [8-10] and refractive error [11-12]. It has also been shown to vary according to ethnicity [13-17].

Intraocular pressure has a mean of 15.7 mmHg +/-2DS [18] and is known to vary according to gender[19-22], age [19,22],refractive error [23-24], diurnal variations [25], posture [26-27], exercise [28], drinking water [29], and central corneal thickness [30-31] amongst others. It also varies according to ethnicity [23,32-33].

The Olympic and Paralympic Games provided a unique opportunity to take a snapshot of the world and examine similarities in CDR and IOP right across the globe. This is the first study to globally map out results for CDR and IOP.

Aims

The aims of this study were to:

Outline normative values for vertical cup-to-disc ratio (CDR) and intraocular pressure (IOP) measurements in a unique sample of competitors and non-competitors at London 2012 according to continents and geographical sub-regions which can be used by future organizers in their planning and provision of large sporting events. This also offers a real opportunity to build up information on competitors by collecting this data from around the world at future events.

Find a suitable tool for mapping results across the world.

Methods

The eye clinic at the London 2012 Olympic and Paralympic Games was housed in a purpose built polyclinic situated in the Athetes' Village [34]. Sixteen volunteer optometrists were recruited for the period of the Olympic Games and eight volunteer optometrists for the Paralympic Games respectively, with consideration given to strength of clinical experience with particular attention paid to those who worked within the hospital eye service, those with experience of voluntary work and those with clinical expertise in areas such as low vision. There were also nine ophthalmologists who provided cover for both the Olympic and Paralympic Games.

The eye clinic was open to all competitors and members of their respective teams. Data from all patients seen at the eye clinic for the Olympic and Paralympic Games were used in this study. All patients underwent a full optometric eye examination and clinical details such as cup-to-disc ratio were recorded using both direct and indirect ophthalmoscope techniques. Intraocular pressures were also recorded via non contact methods using the Topcon TRK-1P (Topcon, Tokyo, Japan). An average of the readings was taken and were used in this study.

Details of the team the patient represented were also recorded. Patients were then subsequently categorized into countries using the United Nations Geographical Sub-regions classification [35].

The data was analyze dusing R statistical software [36] and SPSS version 22. Continent and sub-continent level choropleth maps were produced using GGPlot2 package [37].

In keeping with the Declaration of Helsinki, ethical approval was obtained from City, University of London's Research and Ethical Committee. In addition, permission was granted from the International Olympic Committee.

Results

A total of 2,077 patients (males = 1,513; females = 564) were used for analysis. The mean age across all the continents ranged from 43.44 years in the Americas to 47.11 years in Europe with an overall mean age of 45.12 (SD = 13.62 years) (table 1). A CDR was recorded in 1,566 right eyes (OD) and 1,530 left eyes (OS). Similarly with intraocular pressure, there were 1,621 measurements for the right eye (OD) and 1,615 measurements for the left eye (OS).

Data for OD eyes only was used for analysis. Table 1 shows a summary of the sample used by continent.

Vertical Cup-to-Disc Ratios (CDR)

A Wilcoxon signed-rank test revealed no significant difference in CDR between OD (mean = 0.32, SD = 0.15) and OS eyes (mean = 0.32, SD = 0.15) (Z = -0.966, p = 0.33).

Continents: Mean OD CDR was plotted by continent (figure 1 and 2). The median value was the same across all continents and sub-geographical regions and was 0.30. Africa had the largest CDR with a mean of 0.34 (n = 541) and Europe had the smallest with 0.29 (n = 311). The mean OD CDR was 0.32 (n = 387) for the Americas, 0.29 (n = 311) for Europe, 0.34 (n = 541) for Africa, 0.31 (n = 254) for Asia and 0.33 (n = 73) for Oceania.

There was a statistically significant difference between groups as determined by one-way ANOVA ($F(4,1561) = 6.093$, $p = 0.00$). A Games-Howell post-hoc test revealed that Africa had statistically significantly larger CDRs (0.34 +/- 0.16) than both Europe (0.29 +/- 0.12, p =0.00) and Asia (0.31, 0.15, p=0.04). There were no statistically significant differences between the other continents (p>0.17).

Table 1: Characteristics of sample used by continent

Characteristics	Continent				
	Americas	**Europe**	**Africa**	**Asia**	**Oceania**
n	510	441	698	334	94
Sex M/F	359/151	309/132	520/178	271/63	54/40
Age (mean:range:n)	43.44 (16 – 75) 510	47.11 (16-79) 441	44.47 (13 - 83) 698	46.56 (17 – 80) 334	44.52 (16-69) 94
Age(median:range:n)	45.50 (16 – 75) 510	50.00 (16-79) 441	46.00 (13 - 83) 698	48.00 (17 – 80) 334	46.00 (16-69) 94
R CDR (mean:range:n)	0.32: (0.0 – 0.8): 387	0.29: (0.0 – 0.9): 311	0.34: (0.0 – 0.9) 541	0.31: (0.0 – 0.9): 254	0.33: (0.0 – 0.8): 73
R CDR (median:range:n)	0.30: (0.0 – 0.8): 387	0.30: (0.0-0.9): 311	0.30: (0.0 – 0.9) 541	0.30: (0.0 – 0.9): 254	0.30: (0.0 – 0.8): 73
R IOP (mean:range:n)	16.53: (9 – 26): 404	16.93: (10-29): 325	16:41: (7 – 38): 557	16.95: (8.5 – 24.33): 255	15.45: (8 – 20): 80
R IOP (median:range:n)	16.33: (9 – 26): 404	16.67: (10 –29): 325	16:00: (7 – 38): 557	16.67: (8.50 – 24.33): 255	15.67: (8 – 20): 80

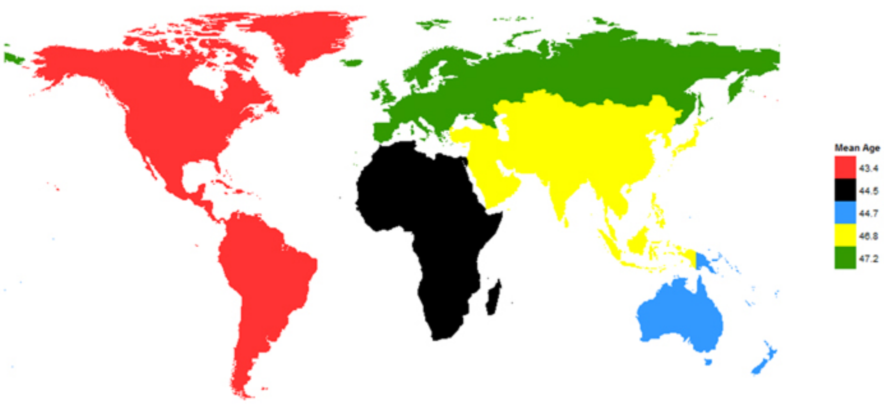


Figure 1: Mean OD vertical cup-to-disc ratio against continent

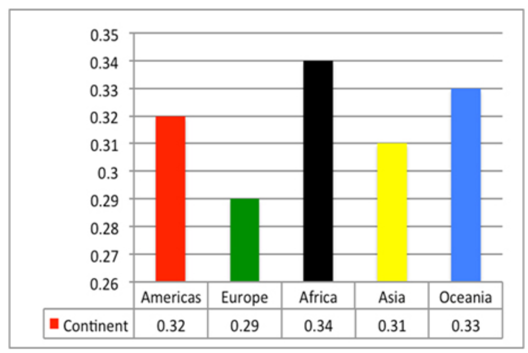


Figure 2: Mean OD vertical cup-to-disc ratio against continent.

Competitors: Competitors (n = 187) and non-competitors (n = 817) at the Olympic Games were compared for differences in CDR. The mean age of the competitors was 26.23 years (SD = 6.18) and 50.86 years (SD = 10.25) for the non-competitors.

A Mann-Whitney 'U' test found significantly smaller CDRs in competitors (mean = 0.29, SD = 0.15) than non-competitors (mean = 0.33, SD = 0.16); (U = 66583.50, p = 0.01).

A small subset of Olympic competitors (n = 41) and non-competitors were matched according to age (within +/- 4 years), gender and sub-continent. The mean age of competitors was 31.5 years (SD = 7.95, 20-65) and the mean age of non-competitors was 32.5 years (SD = 7.71, 17-64).

A Wilcoxon signed-rank test revealed no significant difference in OD CDR between competitors (mean = 0.30, SD = 0.17) and non-competitors (mean = 0.36, SD = 0.17) (Z = -1.810, p = 0.07).

Intraocular Pressure (IOP)

A Wilcoxon signed-rank test revealed a significant difference in IOP between OD (mean = 16.58, SD = 2.96) and OS eyes (mean = 16.88, SD = 3.00) with the OS eye measuring consistently higher (Z = -7.765, p = 0.00).

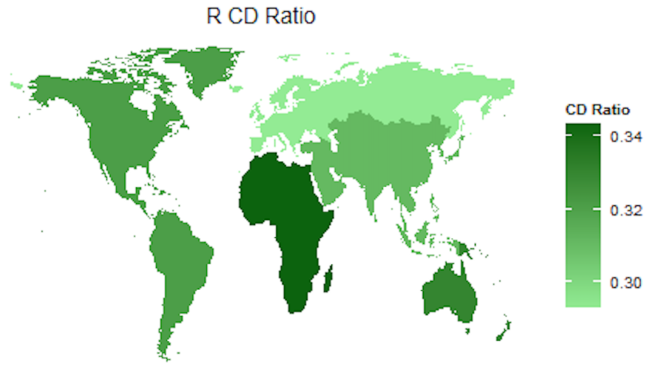


Figure 3: Individual value plots of OD intraocular pressure against continent

Continents: Figure 4 shows the individual distributions for intraocular pressure by continent and figure 4 shows the median OD IOP by continent. Asia had the highest IOPs (mean = 16.95) with Africa having the largest spread of IOPs. The mean OD IOPs was 16.53 (n = 404) for the Americas, 16.93 (n = 325) for Europe, 16.41 (n = 557) for Africa, 16.95 (n = 255) for Asia and 15.45 (n = 80) for Oceania.

Competitors: Competitors (n = 203) and non-competitors (n = 885) at the Olympic Games were compared for differences in IOP.

A Mann-Whitney ‘U’ test found significant lower IOPs in competitors (mean = 16.21, SD = 2.57) than non-competitors (mean = 16.71, SD = 2.87); (U = 79544.50, p = 0.01).

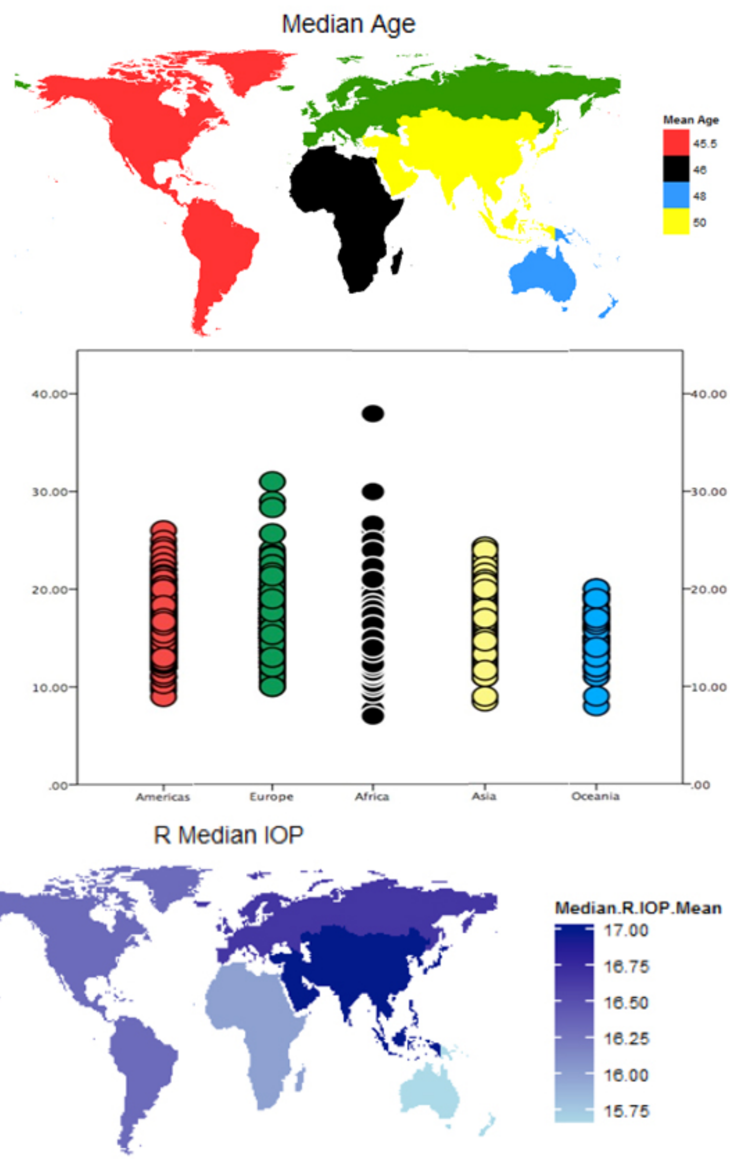


Figure 4: Median OD intraocular pressure against continent

A small sample of Olympic competitors (n = 45) and non-competitors were matched according to age (within +/- 4 years), gender and sub-continent. The mean age of competitors was 32.1 years (SD = 7.54, 22 - 65) and the mean age of non-competitors was 33.3 years (SD = 7.25, 22-65).

A Wilcoxon signed-rank test revealed no significant difference in OD IOP between competitors (mean = 16.14, SD = 2.50) and non-competitors (mean = 16.36, SD = 2.62) ($Z = -0.242$, $p = 0.81$).

Sub-Geographical Regions

Patients were also subdivided into 22 sub-continent areas and the summary of these are shown in Table 2.

Continent	Age	M	F	R Disc	L Disc	R Disc	L Disc	R IOP	L IOP	R IOP	L IOP
				n	n	Mean Median	Mean Median	n	n	Mean Median	Mean Median
Americas	**43.44 45.50**	**359**	**151**	**387**	**376**	**0.32 0.30**	**0.33 0.30**	**407**	**407**	**16.53 16.33**	**16.86 16.83**
Caribbean	44.9 47.0	*160*	*69*	186	184	0.32 0.30	0.33 0.30	185	185	16.52 16.50	16.77 16.67
Central America	41.2 42.5	*74*	*36*	82	79	0.33 0.30	0.34 0.30	82	82	16.60 16.50	16.98 16.67
North America	39.1 37.5	*12*	*8*	11	11	0.28 0.30	0.29 0.30	15	15	16.76 16.67	17.23 17.33
South America	43.4 46.0	*113*	*38*	108	102	0.31 0.30	0.31 0.30	122	122	16.45 16.17	16.87 17.00
Europe	**47.11 50.00 18**	***309***	***132***	**311**	**301**	**0.29 0.30**	**0.30 0.30**	**325**	**322**	**16.93 16.67**	**17.37 17.33**
Eastern Europe	49.33 52.00	*180*	*81*	194	188	0.29 0.30	0.30 0.30	205	203	17.10 17.00	17.66 17.67
Northern Europe	43.22 45.00	*82*	*33*	75	73	0.29 0.30	0.29 0.30	74	73	16.44 16.00	16.71 16.00
Southern Europe	44.85 47.00	*35*	*12*	31	30	0.29 0.30	0.31 0.30	35	35	16.55 16.00	17.00 17.33
Western Europe	45.78 47.00	*12*	*6*	11	10	0.37 0.30	0.37 0.35	11	11	18.27 19.00	17.70 18.00
Africa	**44.47 46.00**	***520***	***178***	**541**	**528**	**0.34 0.30**	**0.34 0.30**	**557**	**552**	**16.41 16.00**	**16.64 16.33**
Eastern Africa	45.2 46.0	*134*	*39*	127	126	0.35 0.30	0.34 0.30	140	138	16.02 15.67	16.14 15.83
Middle Africa	44.8 48.0	*56*	*31*	73	72	0.33 0.30	0.34 0.30	77	74	17.02 17.33	17.05 16.83
Northern Africa	43.6 44.0	*158*	*32*	141	140	0.32 0.30	0.31 0.30	143	143	15.85 15.67	16.08 16.00
Southern Africa	41.6 43.0	*25*	*22*	37	36	0.37 0.30	0.37 0.30	36	36	15.44 14.42	15.78 15.42

Western Africa	45.2 48.0	*147*	*54*	163	154	0.36 0.30	0.36 0.30	161	161	17.18 17.00	17.58 17.67
Asia	**46.56** **48.00**	***271***	***63***	**254**	**251**	**0.31** **0.30**	**0.31** **0.30**	**255**	**257**	**16.95** **16.67**	**17.21** **17.00**
Central Asia	46.50 49.00	*38*	*6*	39	39	0.28 0.30	0.28 0.30	38	38	17.32 17.00	17.13 17.00
Eastern Asia	43.06 45.00	*73*	*30*	88	87	0.33 0.30	0.33 0.30	77	77	17.02 17.00	17.24 17.00
South-Eastern Asia	42.17 40.50	*37*	*9*	31	31	0.35 0.30	0.33 0.30	35	35	16.34 16.00	16.93 17.00
Southern Asia	50.52 50.50	*59*	*7*	45	43	0.32 0.30	0.32 0.30	52	53	16.36 16.50	16.65 16.50
Western Asia	50.60 52.00	*64*	*11*	51	51	0.27 0.30	0.26 0.30	53	54	17.58 17.00	17.93 17.67
Oceania	**44.52** **46.00**	***54***	***40***	**73**	**74**	**0.33** **0.30**	**0.33** **0.30**	**80**	**80**	**15.45** **15.67**	**15.69** **15.67**
Australia and New Zealand	42.96 45.00	*15*	*10*	20	20	0.34 0.30	0.34 0.30	20	20	15.73 16.00	15.89 16.00
Melanesia	43.00 46.00	*13*	*10*	17	18	0.35 0.30	0.34 0.30	20	20	15.42 15.00	15.54 15.17
Micronesia	46.79 50.00	*17*	*12*	23	23	0.31 0.30	0.32 0.30	25	25	15.28 15.00	15.71 16.00
Polynesia	45.00 43.00	*9*	*8*	13	13	0.33 0.30	0.33 0.30	15	15	15.43 15.67	15.60 15.67
TOTAL	**45.12** **47.00**	**1513**	**564**	**1566**	**1530**	**0.32** **0.30**	**0.32** **0.30**	**1621**	**1615**	**16.58** **16.33**	16.89 16.67

Sub-geographical regions-CDRs: There was a statistically significant difference between groups as determined by one-way ANOVA ($F(21,1544) = 2.202$, $p = 0.00$). A Games-Howell post-hoc test revealed that Western Africa had statistically larger CDRs (0.36+/- 0.18) than Western Asia (0.27 +/- 0.14, p=0.02), Eastern Europe (0.29+/- 0.12, $p = 0.01$) and Northern Europe (0.29+/- 0.13, p =0.03).

Sub-geographical regions- IOPs: There was a statistically significant difference between groups as determined by one-way ANOVA ($F(21,1605) = 2.990$, $p = 0.00$). A Tukey post-hoc test revealed that Northern Africa had statistically significantly lower IOPs (15.85 +/- 2.92) than Western Africa (17.18 +/- 2.97, p=0.02), Western Asia (17.58 +/- 2.83, p =0.04) and Eastern Europe (17.10 +/- 3.06, $p = 0.02$).

Discussion

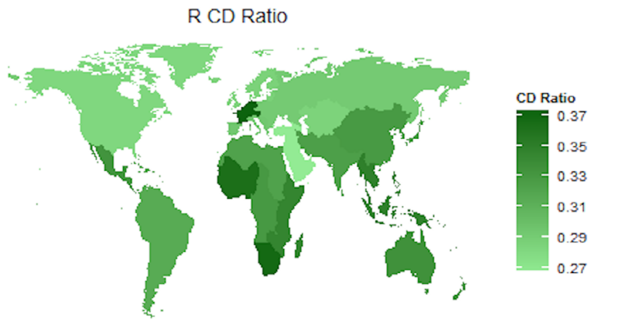
The standard clinical ophthalmic examination usually includes a measurement of cup-to-disc ratios which are usually estimated using direct or indirect methods of ophthalmo scopy. This paper describes the normative data found at the London 2012 Olympic and Paralympic Games that can be used by future organizers in their planning of large sporting events and offers a real opportunity to build up information on competitors by collecting this data from around the world at future events.

This paper analyzed a total of 1,566 OD CDRs and 1,621 OD IOPs from 2,077 patients with a mean age of 45.12 years at the London 2012 Olympic and Paralympic Games. A total of 22 sub-regions were included in the analysis.

Vertical Cup-to-Disc Ratio (CDR)

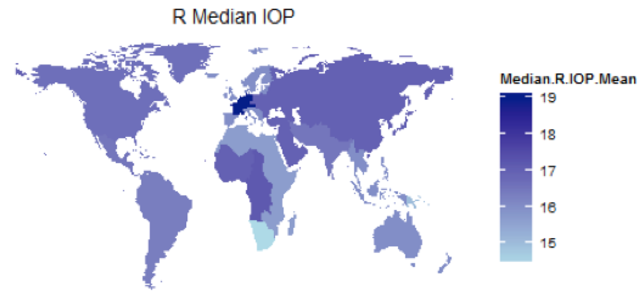
Our study has shown that in a unique sample of competitors and non-competitors at London 2012, Africa had statistically larger CDRs than both Europe and Asia. These findings are consistent with other studies although many of these have measured disc

Figure 5: Mean OD vertical cup-to-disc ratio by sub-continent



There was a statistically significant difference between groups as determined by one-way ANOVA ($F(21,1544) = 2.202$, $p = 0.00$). A Games-Howell post-hoc test revealed that Western Africa had statistically larger CDRs (0.36+/- 0.18) than Western Asia (0.27 +/- 0.14, p=0.02), Eastern Europe (0.29+/- 0.12, p = 0.01) and Northern Europe (0.29+/- 0.13, p =0.03).

Figure 6: Median OD intraocular pressure by sub-continent



There was a statistically significant difference between groups as determined

area as opposed to CDR. These studies have shown that African-Americans have larger disc areas than Caucasians [12,14-17, 38]. Lee et al (2013) observed that Caucasian discs had a smaller area than the other ethnic groups measured in his study (Chinese, Filipino, African and Hispanic) [14]. Marsh et al (2010) compared disc area and again found African-American disc area to be significantly larger than Caucasian discs [38]. Tsai et al (1995) showed that African-Americans had significantly larger discs than Caucasians with Asians having medium sized discs [16]. Seider et al (2009) also found that White American disc area were significantly smaller than in other ethnic groups (Asian, Filipino, African, Hispanic-American) [15].

Within geographical sub-regions, we have shown in our sample that Western Africa had statistically larger CDRs than Western Asia, Eastern Europe and Northern Europe. Ramrattan et al (1999) found a weak association with disc size and height in medium sized adults [9].

Xu et al (2011) found no significant differences in disc size or intraocular pressure between men and women. It therefore seems unlikely that our results would be affected by gender differences [39]. In addition, Jonas (2005) noted that refractive error and disc size was relevant for high hypermetropia and myopia (>-8.00DS and >+4.00DS) [11].

Intraocular Pressure (IOP)

Our study has shown that in a unique sample of competitors and non-competitors at London 2012, Oceania have statistically lower IOPs than the Americas, Europe or Asia.

Within geographical sub-regions, we have also shown in our sample that Northern Africa had statistically lower IOPs than Western Africa, Western Asia and Eastern Europe. In addition, Eastern Africa had statistically lower IOPs than Eastern Europe. Shimmyo et al (2003) found that African Americans had thinner central cornea thickness resulting in lower IOPs than Asians, Caucasians or Hispanics [33]. In our study, we used the Topcon TRK-1P for measuring IOP which was set to compensate for corneal thickness.

The finding that the left eye was consistently higher than the right eye for intraocular pressure measurements was consistent with the findings of Bhorade et al, 2009 who also reported finding this and is likely to be an order effect as the Topcon TRK-1P measures IOPs in the OS eye first [40].

Competitors

Competitors were found to have smaller CDRs and lower IOPs than non-competitors. This is likely to be because competitors are younger with a mean age of 26.17 years (median = 25.00 years) compared to non-competitors who had a mean age of 51.25 years (median = 52.00 years). It has been shown that CDR increases by approximately 0.1 over a 40-year period from the age of 30 to 70 years [7,41]. In addition, other factors such as refractive error and ethnicity were not accounted for although Varma et al (1994) found no differences in disc size associated with age or gender [10].

Competitors were also found to have lower IOPs than non-competitors. Again this is likely to reflect that competitors were younger than non-competitors as intraocular pressure has been shown to increase with age [19,22] although in some ethnic groups such as the Japanese, intraocular pressure has been shown to decrease with age [21]. However, a much larger study found that there was no association with age and IOP after adjusting for confounding variables [42] although Hong et al (2014) have shown a reduction in IOP associated with exercise so it is possible that this is why the competitors had lower IOPs [28].

However, when a sample subset of competitors was matched with non-competitors for age, gender and sub-continent, competitors were found to have smaller CDRs and lower IOPs than non-competitors although this was not significant. It is possible that the sample size used was too small to detect any levels of significance and this might be worth investigating at future sporting events.

Limitations of this Study

One of the challenges faced with studies such as these is that the data available tends to be ad hoc and may not be what you would choose to use if you were planning a research project. In an ideal world, you would measure optic disc parameters using an objective instrument such as an OCT. Again this is reliant on practitioners correctly lining up their patients and operating the instrument correctly but it is still less prone to errors than a subjective measurement such as CDR.

CDR is used as standard in optometric practice [43-44]. It is well documented that there is variability in measurements between practitioners as well as variability with the same practitioner [2-5]. It is possible that the large number of optometrists (n = 24) and ophthalmologists (n = 9) could introduce variability into the measurements. Our optometrists were experienced clinicians who either worked in the Hospital Eye Service or who had good experience in optometric practice. Patients were seen in the order they arrived and all optometrists volunteered for a minimum of ten days, so it was impossible for one clinician to examine patients from one country or team or for all the CDR measurements to be taken by the same clinician. It is therefore not unreasonable to assume that any variations in their assessment of the CDR would cancel each other out.

Another limitation of this study is the small samples when the continents were divided into sub-geographical regions. However, the authors hope that more data can be added to this set from future Games to build up an understanding of ophthalmic characteristics across the globe. It is also possible that this data may not be generalizable to other, non-athletic, populations.

The primary reason we were in the eye clinic was to see competitors and their support teams who generally wished to be seen as quickly as possible so they could return to their work or training sessions within their respective teams. In addition, the overwhelming majority of patients did not speak English so to run a formal research project was fraught with difficulties through the language barrier and would have impacted upon our provision of quality eye care.

Conclusions

Being allowed to use data from the London 2012 eye care clinic is a unique opportunity to sample a snapshot of the world and report on some baseline data that may well have benefits globally. Our study has shown that in a unique sample of competitors and non-competitors at London 2012, Africa had statistically larger CDRs than both Europe and Asia. Within geographical sub-regions, we have shown that Western Africa had statistically larger CDRs than Western Asia, Eastern Europe and Northern Europe.

In addition, our study has shown that Oceania had statistically lower IOPs than the Americas, Europe or Asia. Within geographical sub-regions, we have also shown that Northern Africa had statistically lower IOPs than Western Africa, Western Asia and Eastern Europe. In addition, Eastern Africa had statistically lower IOPs than Eastern Europe.

Finally, our study found that competitors had significantly smaller CDRs and lower IOPs than non-competitors.

This study maps out normative values on CDR and IOP by continent and geographical sub-regions in a unique sample of competitors and non-competitors at London 2012. The authors outline what the likely clinical findings are in this population which should be of interest to those involved in organizing ophthalmic services at future events. This is the most comprehensive data set obtained from any Olympic and Paralympic Games to date and the authors present it as part of building up the body of knowledge of normative results that you would find at large sporting events. It is hoped that data from future Olympic and Paralympic Games can be added to these findings to produce larger, more comprehensive data sets which can offer real help for future planning of services.

There was a statistically significant difference between groups as determined by one-way ANOVA ($F(21,1605) = 2.990$, $p = 0.00$). A Tukey post-hoc test revealed that Northern Africa had statistically significantly lower IOPs (15.85 +/- 2.92) than Western Africa (17.18 +/- 2.97, p=0.02), Western Asia (17.58 +/- 2.83, p =0.04) and Eastern Europe (17.10 +/- 3.06, p = 0.02).

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